TREATMENT OF White Pines INFECTED WITH Blister Rust

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THE WHITE or five-needled pines form a renewable national resource of great importance to present and future forestry in this country. They also are highly valued and widely used in ornamental planting, recreation areas, watershed protection, and the prevention of soil erosion.

In many areas white pines have been killed or seriously damaged by blister rust, a destructive fungus disease that reached this country from Europe about 1898. The fungus spreads from diseased white pines to *Ribes* (currant and gooseberry plants), from *Ribes* to *Ribes*, and from *Ribes* back to pines. It cannot spread from pine to pine.

White-pine blister rust is controlled by the eradication of *Ribes*. This removes the source of the pine-infecting spores and effectively protects the pines, but does not cure trees already diseased. Infected trees, if not too badly damaged, however, can be saved by cutting out the diseased parts. This treatment, which supplements *Ribes* eradication, is used on infected ornamental pines and to some extent on plantations and native growth of high value.

Successful treatment of the diseased pines depends largely upon the workman's ability to find and remove the cankers. Infected branches are cut off flush with the next healthy branch or with the trunk. Cankers on large limbs and on trunks are treated by removing the diseased bark and a surrounding strip of healthy bark. If the canker extends more than half way around the limb or trunk, it is best to remove the entire limb or tree. Treated pines should be reinspected at least every 3 years until no more cankers are found. The extent to which the treatment of diseased pines and their protection from reinfection by *Ribes* eradication is economically practicable depends largely upon their forest and esthetic values.

This bulletin presents information concerning the blister rust disease and the symptoms by which it can be identified, and describes methods of treatment that will save many valuable infected white pine trees.

It replaces Department Circular No. 177, Treatment of Ornamental White Pines Infected with Blister Rust.

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TREATMENT OF WHITE PINES INFECTED WITH BLISTER RUST

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MANY WHITE PINES already have been killed or seriously damaged by white-pine blister rust, a fungus disease that, if uncontrolled, is capable of destroying these trees over extensive areas. This disease was first reported in the Eastern States in 1906 and in the Western States in 1921, but later findings indicate that it probably was first introduced from Europe into New England about 1898 and into British Columbia, Canada, in 1910. Between 1898 and 1912 many shipments of infected white pine nursery stock reached this country and were planted in several Eastern States before Federal plant quarantine laws were enacted. When authority to establish quarantines was granted to the Department of Agriculture, in 1912, the further introduction of blister rust host plants was prohibited, and, in cooperation with the affected States, an attempt was made to eradicate the disease by locating the white pines already imported and destroying those found infected. It soon became apparent, however, that the fungus already had established itself in the native forests of the Northeastern States and could not be eliminated.

The blister rust fungus requires currant and gooseberry bushes, commonly called *Ribes*,[1] to complete its life cycle, and practical control of the rust is accomplished by eradicating *Ribes* growing in the vicinity of white pines. Efficient control practices have been developed through continued experience in many parts of the country where white pines are important forest trees. Millions of acres of pine growth have been protected, but in some areas the natural spread of the disease has been rapid and much pine infection occurred before

[1] Throughout this paper "*Ribes*" will be used to mean currant and gooseberry plants.

control measures could be applied. More or less infection of white pines continues to take place each year in unprotected areas within the infected regions. Although *Ribes* removal protects white pines, it does not cure those already diseased, and, unless treated, many of these trees will die. Infected pines often can be saved by cutting out the cankers, but the extent to which this treatment may be practicable economically depends largely upon their forest and esthetic values.

FOREST AND ESTHETIC VALUES OF WHITE PINES

Trees are generally recognized as providing a useful and valuable natural resource. Among our many native forest and ornamental trees the white pines [2] rank near the top in economic and esthetic importance. One or more of the eight native species are found in many States (fig. 1), and as a group they may be distinguished from other trees by their needles, which are arranged in clusters of five.

The eastern white pine, western white pine, and sugar pine are important timber species that have an estimated stumpage value of over $300,000,000 and, in addition, an immature potential timber crop consisting of millions of acres of natural and planted young growth. These trees are favored in forest practice because of their rapid growth, high yield, and excellent wood, which is prized for manufacturing purposes and usually brings about $30 per thousand board feet at the mill. During the 11-year period 1925 to 1935 more than 13,500,000,000 board feet of white pine was harvested in the United States, with a mill value of over $400,000,000. In sections where the logging and milling industries require a continuous supply of white pine timber, the employment of labor and the welfare of the population depend upon the maintenance of these trees in the forest. Usually the white pines are more valuable and profitable than associated species, and if they are destroyed, not only will the net productivity of the land be decreased, but future crops will be correspondingly less valuable. The five-needled pines also furnish protection for watersheds and wildlife and help prevent soil erosion on large areas of land.

The esthetic values, although possessed by all native white pines, are largely intangible. Millions of these trees are growing in parks, along roadsides, and around homes where they add to the beauty of the landscape and increase property values. Some are used for windbreaks to protect buildings, crops, and livestock, to furnish shade, and to improve the appearance of the farms. Others are planted as ornamental trees and used in mixtures with deciduous trees to give desirable contrasts in landscaping. Numerous stands are utilized for picnic groves and camp sites. In public parks and in recreational and winter sports areas the white pines are an important scenic asset. An accurate determination of these values in dollars and cents is not practicable, but in the aggregate such values are very high and in some regions probably exceed timber values.

[2] The white pines native to North America are (1) eastern white pine, *Pinus strobus* L.; (2) western white pine, *P. monticola* Dougl.; (3) sugar pine, *P. lambertiana* Dougl.; (4) limber pine, *P. flexilis* James; (5) whitebark pine, *P. albicaulis* Engelmann; (6) bristlecone pine, *P. aristata* Engelmann; (7) foxtail pine, *P. balfouriana* Murray; and (8) Mexican white pine, *P. strobiformis* Engelmann.

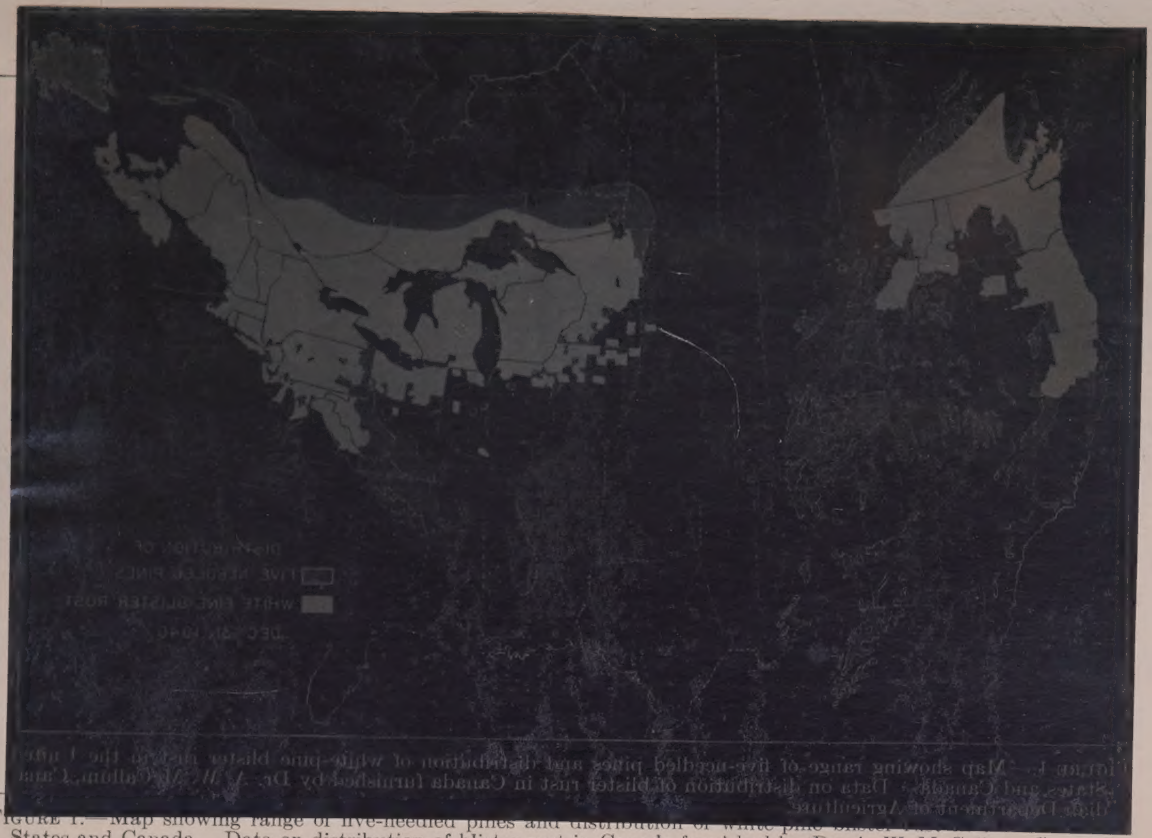

FIGURE 1.—Map showing range of five-needled pines and distribution of white pine blister rust in the United States and Canada. Data on distribution of blister rust in Canada furnished by Dr. A. W. McCallum, Canadian Department of Agriculture.

THE DISEASE

DISTRIBUTION OF THE RUST

Blister rust is more or less prevalent on white pines and *Ribes* in the New England States, New York, New Jersey, Pennsylvania, Maryland, Virginia, West Virginia, Ohio, Michigan, Wisconsin, Minnesota, Iowa, Montana, Idaho, Washington, Oregon, and northern California

FIGURE 2.—Young blister rust canker showing swollen bark. The fungus entered the bark through the cluster of needles which are now dead but still attached to the canker.

and has been found on *Ribes* in Delaware, Indiana, and Illinois (fig. 1). It is advancing southward by natural spread in the sugar pine forests of California and in the white pine forests of the southern Appalachian Mountains. It appears probable that eventually the rust will spread throughout the white pine forest areas of this country, including the central Rocky Mountain region, where such high-altitude species as limber pine, whitebark pine, and bristlecone pine are found. In southern Canada the disease extends from Nova Scotia to western Ontario, and it also occurs in the Provinces of Alberta and British Columbia.

LIFE CYCLE OF THE FUNGUS

Blister rust is caused by *Cronartium ribicola* Fischer, a fungus that must grow alternately on white pines and *Ribes* in order to complete its life cycle. It reproduces and spreads by means of different kinds of minute seedlike bodies known as spores. The fungus enters white pines through the needles and then grows into the bark, where it continues to develop and form diseased areas, called cankers (fig. 2). The cankers mature in 2 or more years after the fungus enters the needles, and then from April to June white sacs or blisters containing orange-yellow spores, called aeciospores, push through the diseased bark. The blisters soon break, and the powderlike spores are scattered by the wind over large areas. Thereafter new blisters may be produced each spring in the cankered bark as long as the fungus remains alive.

Some of the aeciospores fall on *Ribes* and, after germinating, infect the leaves. In about 2 weeks small, orange-yellow pustules appear on the under surface of the diseased leaves. These pustules burst, liberating the urediospores, which infect *Ribes* leaves on the same and nearby bushes. During the summer and fall the fungus develops brownish, hairlike columns of teliospores on the under surface of the diseased *Ribes* leaves (fig. 3). These columns, which are about one-sixteenth of an inch long, remain upon the *Ribes* leaves, where they germinate and produce spores of another kind known as sporidia. The sporidia are freely distributed in the vicinity and infect white pine needles upon which they lodge, thus completing the life cycle.

DISPERSAL OF SPORES

The different kinds of spores that spread white-pine blister rust are wind-borne. The aeciospores, produced on the pine, may remain alive for several months and are carried by the wind to *Ribes* leaves for distances up to 150 or more miles. A group of diseased pines, therefore, may infect *Ribes* over an extensive area. The urediospores produced on the under surface of diseased leaves are spread locally by the wind to other nearby *Ribes* leaves on the same and other bushes. With favorable temperature and moisture conditions, as many as seven generations of urediospores may be produced in one growing season, thus greatly increasing the amount of infection on these plants.

The columns of teliospores which follow the uredinial stage on the infected *Ribes* leaves produce the sporidia that infect the pines. These sporidia are very delicate and short-lived. They are distributed by the wind and usually infect pines within a radius of a few hundred

feet of the diseased *Ribes*, although in some instances sporidia from *Ribes nigrum* may cause infection for distances up to about 1 mile. *Ribes*, however, are scattered throughout the areas where white pines grow, and, as each bush is a possible source of sporidia, the fungus in any one season may cause widespread pine infection. The amount of infection occurring annually on white pines and *Ribes* varies with weather conditions, being light in some years and heavy in others. Also, the rate of infection is influenced by some species of white pines

FIGURE 3.—Lower surface of currant leaf showing hairlike columns of teliospores which produce the spores that infect white pine.

and *Ribes* that are more susceptible to the disease than others and by the slower spread of the rust on hot, dry sites than on cool, moist sites.

DAMAGE TO WHITE PINES

Blister rust usually infects more of the well-developed and better formed trees than the smaller, more slowly growing individuals. It spreads back and forth between white pines and *Ribes* each year, causing on the pines an accumulation of cankers that kill the trees (fig. 4). The fungus kills by girdling the branches and trunks. Cankers on the trunks retard the growth of the trees and often so

weaken the stems that the tops snap off at the point of girdling. The early stages of pine infection are so inconspicuous that diseased trees may be present in pine stands for a number of years before they are discovered. The owners usually first notice the rust when the death of some of the smaller trees or of the branches of larger ones attracts their attention.

The smaller the pines, the more quickly they are killed by the rust. The elapsed time between needle infection and the death of the trees

FIGURE 4.—Ornamental white pines killed by blister rust.

varies from a few years for young pines to 20 or more for mature trees. This allows owners sufficient time to salvage infected merchantable pines if they are found before the disease causes their death. Sometimes, however, when *Ribes* are very abundant, nearly all the branches may be killed in a relatively short time, and under these conditions large trees, particularly of the more susceptible species, may die from rust infection within a few years even though the trunks are not invaded by the fungus.

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Blister rust, if uncontrolled, is capable of destroying the white pines in areas where *Ribes* are present among or near the trees. The greatest damage in this country has occurred in natural white pine growth, forest plantings, and ornamental trees up to 30 years of age where the *Ribes* either have not been eradicated or were not removed soon enough to prevent severe pine infection. As a result numerous ornamental pines and stands of young growth have been severely damaged and in many cases completely ruined. The killing of the smaller trees in forest areas not only depletes the stands and leaves undesirable openings but also greatly reduces and often prevents natural restocking with white pines. Large pine trees are killed gradually, whereas young trees die in a relatively short time when attacked by the rust. Therefore older forest and ornamental trees have thus far suffered the least damage, but many of them have been badly injured and killed. The destruction of merchantable trees, being relatively slow, continues without attracting much attention because such losses mostly occur as single trees and small groups of trees scattered throughout forest areas. In the aggregate, however, the loss at present of forest trees over 30 years of age from blister rust is greater than most owners realize. In ornamental pines the infection is not so apt to go unnoticed as they are continually under observation and any injury is soon detected. Such trees, however, may become unsightly from the death of many limbs, and frequently their esthetic value is greatly reduced or destroyed many years before they are killed (fig. 5).

HOW TO RECOGNIZE INFECTIONS

The successful treatment of infected trees depends primarily on finding and removing all cankers. In order to recognize them, a knowledge of the symptoms of the disease on pines is necessary. This can be obtained by the study of descriptions, illustrations, and specimens of the disease, supplemented by actual field experience in identifying cankers and in distinguishing them from other injuries.

YOUNG CANKERS

The development of blister rust cankers from the time the needles are infected until the first blisters are produced requires a minimum period of 2 years but usually takes from 3 to 4. Several symptoms of the disease appear during this period. The first bark symptom is a circular, orange-yellow spot, about one-fourth inch in diameter, around the base of a diseased needle cluster. It requires so much time to find these discolored spots that they are of no practical use for locating cankers in treating infected trees.

As the fungus continues to grow in the bark, the diseased areas, or cankers, gradually increase in size. In many cases they appear as distinct spindle-shaped swellings on branches and stems, but in others this swelling is absent or only slightly evident although the diseased bark is usually somewhat thicker than healthy bark. The cankers are outlined by a more or less distinct, narrow band of yellowish discolored bark which indicates the approximate margin of the advancing growth of the fungus (fig. 6, *a*). Inside this band the diseased bark is a lighter shade of green than the healthy bark, or sometimes a bronze color. During the summer and fall preceding the appearance

FIGURE 5.—Trees so badly damaged by blister rust that they cannot be saved. *A*, A fatally diseased roadside tree in the foreground. Note the large stem canker covered with pitch and the numerous branches killed by rust. *B*, Blister rust has killed so many branches in this tree that it cannot be saved.

FIGURE 6.—A fruiting blister rust canker as it appears in the spring; *a*, discolored, yellowish bark or growing margin of canker; *b*, dark reddish-brown to black pycnial scars; *c*, orange-yellow blisters; *d*, rough, cracked bark of previous fruiting area.

of the orange-yellow blisters, small drops of a faintly yellow fluid exude from the diseased bark within and just back of the yellow margin of the cankers. These drops dry up, leaving small, irregularly shaped spots called pycnial scars (fig. 6, *b*). They vary from dark reddish brown to nearly black in color and positively indicate blister rust infection. When cankers reach this stage of development they are old enough to be easily found.

FRUITING CANKERS

The following spring, from April to June, blisters push through the bark in the pycnial area formed the previous summer (fig. 6, *c*). These blisters, or sacs, consist of a thin white membrane enclosing a mass of orange-colored aeciospores, which show through the membrane and give the blisters an orange-yellow appearance that is very distinctive and noticeable. The membrane bursts, and the exposed aeciospores are blown away by the wind, leaving small holes or pits in the bark. These holes have ragged edges to which particles of the torn white membrane cling for a short time after the spores have been dispersed. Where the blisters emerged the bark dies and becomes rough and broken by irregular cracks (fig. 6, *d*). A canker may continue to fruit for many years.

The fungus continues to grow outward into the healthy bark both laterally and at either end of a canker. The annual growth of the fungus in the bark is more rapid in large branches than in small branches or twigs. The fungus works back from the twigs into the larger branches and trunk and kills the affected parts as it proceeds.

A fully developed canker has several symptoms by which it can be identified. The advancing margin of the diseased area may be recognized by the narrow, yellowish band of discolored bark. Inside this band is the pycnial area bearing the pycnial scars. Next comes the current season's fruiting zone, where orange-yellow blisters appear between April and June. Then comes the fruiting area of previous seasons, with its roughened, irregularly cracked bark (fig. 7). This portion of the canker may appear somewhat sunken or constricted, especially when located on the trunk.

After a canker girdles a branch or stem the green needles above the diseased area turn yellow and die. They then become dark brown or reddish and later drop, leaving the dead branch bare of needles. The dead and dying branches are called "flags" and are very helpful in locating cankers. The cankers distinguish them from flags caused by other injuries. The death of a branch or stem beyond and above the point at which it has been girdled does not stop the downward growth of the fungus as long as the branch or stem below the canker remains alive. This enables branch cankers to extend downward to the stem, but if the entire branch dies before the stem is reached, the fungus also dies. As this happens frequently, many cankers die before reaching the trunk. Those cankers which live for a number of years continue to increase in size and may extend along the branch or stem for several feet. An infected tree may have several cankers varying in size and development and ranging from young to old fruiting infections.

FIGURE 7.—Old blister rust canker showing rough, cracked bark of former fruiting areas and blisters of the current season pushing through the live bark. Note the constriction near the center of the canker.

VARIATIONS IN CANKERS

The appearance of cankers, as described above, particularly that of older cankers, is often so altered by the attacks of secondary fungi insects, and rodents and from pitch exudation as to make identification more difficult.

Old stem cankers are frequently more or less obscured by pitch The pitch runs down the trunk in streaks and forms a hard, white layer which usually covers part of the canker (fig. 8, *A*). These white

FIGURE 8.—*A*, Canker on trunk partly obscured by white pitch streaks. *B*, Canker attacked by secondary insects, showing borings at the left. *C*, White patches of wood where rodents have eaten part of the cankered bark. *D*, Canker attacked by secondary fungi; at the upper end are blisters; below, the smooth, dead bark has been killed by secondary fungi, and the canker is somewhat constricted.

pitch streaks are useful in locating cankers. They may be misleading in identifying cankers unless associated with other blister rust symptoms, because a similar flow of pitch may result from injuries due to other causes.

Insects may attack trees that are weakened by blister rust cankers and hasten their death. Some insects bore directly into the bark and wood of old cankers, where their presence may be revealed by small accumulations of a mixture of pitch and wood borings on the

surface of the diseased bark (fig. 8, *B*). This may lead inexperienced observers to think that the injury is due to insects, when in reality the primary cause is blister rust infection and this has been followed by the secondary attack of insects.

Conspicuous white patches of barkless wood in cankered areas indicate the work of squirrels, chipmunks, mice, or other rodents (fig. 8, *C*). These rodents often gnaw the diseased bark of blister rust cankers during the winter and early spring when other food is scarce, but enough usually remains to permit continued growth of the fungus and to identify the cankers. Although rodent feeding results in some reduction of the volume of aeciospores that otherwise might have been produced the next spring, it does not seem to slacken the growth of the cankers materially. Similar, but usually much larger, areas of barkless wood on white pines may be caused by porcupine feeding, particularly in forest areas. These may be recognized by the absence of blister rust symptoms.

Blister rust cankers are sometimes attacked by secondary fungi that invade and kill the rust-infected bark. These fungi may follow the advancing margin of a canker so closely that the production of blisters is prevented, or they may kill all the cankered bark. In the latter case the blister rust fungus dies, as it can live only in live bark. The bark killed by the secondary fungi is usually smooth and brown and often has small, black spore pustules on its surface. The attacked cankers, particularly those on the trunk, have a sunken, constricted appearance. Sometimes the diameters of the trunks are greater just above the diseased areas, and this emphasizes the constricted appearance of the cankers. If only a part of the canker is affected by the secondary fungi, the remaining live portion can be identified by some of the blister rust symptoms previously described (fig. 8, *D*).

The different symptoms of blister rust infection on white pines that can be used to identify cankers are summarized in table 1.

TABLE 1.—*Typical symptoms for identifying blister rust infections on white pines*

Canker symptoms	Young cankers	Old fruiting cankers
General shape	Distinct spindle-shaped swellings of bark on twigs, branches, and small stems. This symptom is absent or only slightly evident in some cankers.	Same as for young cankers. The general outline of trunk cankers is roughly diamond- or spindle-shaped, and the diseased bark is thicker than normal.
Pycnial scars	Irregularly shaped spots; dark reddish brown to nearly black in color; variable in size but averaging about ⅛ inch in diameter.	Same as for young cankers.
Margin of cankers	Narrow band of yellowish discolored bark around margin of canker. Inside this band the bark is a lighter shade of green or sometimes a bronze color. Sometimes yellowish margin is very indistinct.	Do.
Orange-yellow blisters	Outer white membrane enclosing orange-yellow aeciospores. These blisters appear from April to June.	Do.
Pits left by blisters	Small pits or holes with ragged edges left by blisters. Small pieces of white membrane remain attached to the edges for a short time after dispersal of the aeciospores.	Do.

TABLE 1.—*Typical symptoms for identifying blister rust infections on white pines* Continued

Canker symptoms	Young cankers	Old fruiting cankers
Cracked bark of old fruiting areas.	Bark is rough and broken by irregular cracks in area where first blisters were produced.	Same as for young cankers, but area of cracked bark is greatly enlarged by the annual production of new blisters and sometimes has a sunken or constricted appearance.
Flags	Dying and dead branches with yellowish, dark-brown, or reddish needles.	Same as for young cankers, except that after the needles drop the flags appear as bare, dead branches.
Insect injury	Usually none	Small accumulations of wood borings mixed with pitch on surface of cankers.
Rodent injury	Patches of white wood where bark was gnawed by rodents.	Same as for young cankers.
Pitch exudation	Usually none	Trunk cankers more or less covered by white streaks of pitch that often extend some distance below the canker.
Secondary fungi	Canker has sunken or constricted appearance. The bark is all or partially dead, usually smooth, brown in color, and often has small, black spore pustules in the surface.	Same as for young cankers. Diameter of trunk may be greater just above stem cankers, emphasizing constricted appearance.

When table 1 is used, it should be understood that some of the symptoms mentioned may be lacking and others so obscured by pitch as to be of no value in identifying a particular canker. All the symptoms should be kept in mind and reliance placed upon some combination of those found. Usually enough different symptoms of the disease are visible at all times to permit positive identification, and field experience will soon enable workmen to recognize most branch and stem cankers quickly.

WHITE PINES WORTH TREATING

Infected pines are worth treatment only when the esthetic or the forest values involved are sufficient to justify the cost. Even then such treatment ordinarily should not be undertaken until the trees have been protected from further infection by the eradication of *Ribes*. In practical work the cost of canker removal has ranged from a few cents for small trees with one or two branch infections to several dollars for mature trees with stem and branch cankers.

ORNAMENTAL TREES

The treatment of infected white pines around homes, in parks, along roadsides, and in recreational areas such as camp sites, picnic groves, country clubs, and summer and winter resorts is desirable, but a question will often arise as to whether a particular infected ornamental tree is worth treating. This question must be answered largely by the owner, as it depends upon the tangible or intangible value of the tree and the extent to which it has been injured by blister rust. The cost of treating ornamental pines usually will be less than the cost of their removal or replacement.

FOREST TREES [3]

In plantations, stands of natural reproduction, and farm wood lots containing young trees up to 15 years of age that are 20 percent or more infected, the owner may find it desirable to combine canker removal on selected crop trees with a pruning operation to increase the value of the lumber.[4] Ordinarily, in order to reduce the amount of work in pruning operations, only the most vigorous trees which are expected to form the final crop, with a few extra for safety, are treated; the remaining trees may serve as "nurse" trees, or "trainers," for the crop trees, or they may be salvaged for fuelwood or other purposes. Such treatment of crop trees should by all means provide for the elimination of cankers. White pines with stem cankers should not be selected as crop trees. The pruning operation removes the cankers on the lower branches and increases the amount of knot-free wood, and thereby may increase the value of the lumber by as much as $15 per thousand board feet over unpruned trees. A few cankers may be found on the upper branches, and these should be removed when the trees are pruned.

In older stands, ranging from 15 to 60 years old, thinning operations may be carried out to obtain maximum growth of selected crop trees and to remove small material that may be marketable. As a general practice, no attempt should be made to remove stem cankers from forest trees or branch cankers in stands over 15 years old. The treatment of stem cankers is too costly, and the removal of branch cankers becomes less practicable on the larger trees. If the fatally infected trees are few and scattered through the stand, they may be removed and utilized. Where they occur in groups, some of the diseased trees that will live several years may be left to serve as trainers for crop trees, to provide protection from wind throw, and to prevent openings in the stand favorable for *Ribes* regrowth. Those that will soon die should be removed. When a stand is so badly infected as to call for the removal of many more branches or trees than ordinary pruning or thinning operations require, it may be preferable to clear-cut it and use the wood before the trees actually die. Such cutting should, of course, be done in such a manner as to provide a seed supply for the new stand of trees.

In general, pruning programs for eastern white pine can be made profitable and, following *Ribes* eradication, have the added advantage of being beneficial from a blister rust control standpoint. These measures have their widest application in pure even-aged stands, but, as good forest management becomes more widespread, mixed all-aged stands will tend to increase and receive consideration in pruning and thinning operations. Treated crop trees should be reinspected after 3 years to remove any blister rust cankers which may have been missed during the first treatment and which, if left, would be fatal. The discussion of forest trees in this section refers primarily to eastern white pines, but pruning and thinning may prove desirable, under some conditions, in treating infected stands of western white pine and sugar pine. Experience with these latter species is too limited at this time to provide a basis for describing conditions that would justify canker removal.

[3] Part of the information in this section and the sections on pruning and thinning forest trees was supplied by the Northeastern Forest Experiment Station, United States Forest Service.

[4] PAUL, BENSON H. KNOTS IN SECOND-GROWTH PINE AND THE DESIRABILITY OF PRUNING. U. S. Dept. Agr. Misc. Pub. 307, 36 pp., illus. 1938.

EFFECTIVENESS OF TREATMENT

Experiments in treating infected eastern white pines have shown that such trees can be saved by removing branch and stem cankers. In this work the rust was successfully eliminated in all cases where the diseased branches were cut off 4 inches or more back of the yellowish band of discolored bark which marks the approximate edge of a canker. Very good results were obtained in treating stem cankers when all the diseased bark and a strip of the apparently healthy bark extending beyond the canker margins from 1½ to 2 inches along the sides and 3 to 4 inches at each end were removed. These experiments have been supplemented by a large amount of practical work on thousands of diseased pines ranging from young trees in plantations to mature ornamental pines around homes and in public parks. The results have been generally satisfactory although not always fully effective. In some cases cankers were missed, and in others they were not cut a great enough distance from the yellowish margin to remove all the infected bark. This allowed the fungus to continue its growth, and sometimes the stems became so badly diseased before they were reexamined that the affected trees could not be saved.

Although canker removal has been confined largely to eastern white pine, it probably would be equally effective for other five-needled pines if the same safety margins were allowed. In a study made by other workers on western white pine the rust mycelium was found to extend in the bark from ⅕ inch to 1⅓ inches beyond the discolored margin at each end of the canker, with a few cases of greater extension. This is about the same as found in eastern white pines. The widths for the strip of healthy bark recommended for removal in treating cankers are much greater than these distances, but this is considered necessary in practical work because of the difficulty encountered in many cases of accurately determining the exact edge of the discolored margin of the canker.

The mycelium of the fungus is known to penetrate the wood for a short distance beneath the diseased bark. The penetration is greatest near the center of the canker and decreases toward its margins. At the edge of the canker there is practically no penetration of the wood by the fungus. In the limited number of treated cankers on which accurate data are available there is no evidence of the fungus spreading from the infected wood to the healthy bark, and it is assumed that the removal of the diseased bark plus a surrounding strip of healthy bark results in the ultimate death of the mycelium in the wood.

TREATMENT OF FOREST STANDS

The method of treatment depends on the location of the cankers and whether the pines are ornamental or forest trees. Branch cankers are eliminated by cutting off the infected branches, and those on trunks, and sometimes those on large limbs, by removing the diseased bark. These methods are followed in treating both ornamental and forest trees. In the case of forest trees, however, it may be advantageous to combine elimination of cankers with pruning and thinning operations.

PRUNING FOREST TREES [5]

Experience with white pine in central New England shows that pruning is profitable on trees less than 4 inches in diameter when it can be done at the rate of 75 or more linear feet of trunk per man-

FIGURE 9. Pruning operation in young stand of white pine that removes infected lower branches and at the same time improves the quality of timber.

hour. Pruning should be delayed until the crowns of the trees are well enough developed to permit judgment as to which ones will dominate the others and therefore be likely to form good crop trees,

[5] More detailed information on pruning trees will be found in Farmers' Bulletin 1892, Pruning Southern Pines, by William R. Mattoon, which may be secured free of charge by application made to the Office of Information, United States Department of Agriculture, Washington, D. C.

and until one can be fairly certain that the butt log (the first 17 feet) will be straight and unweeviled. It should seldom be done on trees larger than 10 inches in diameter. From 150 to 300 crop trees per acre should be chosen for treatment, which means a spacing of 17 by 17 feet and 12 by 12 feet, respectively. If a large number of noncrop trees are infected, it may be preferable to cut them down, rather than go to the expense of pruning them. Fall or winter is the most convenient time to prune. Experience indicates that the pruning should be no higher than half the total height of the tree; thus a tree 16 feet high could safely be pruned to a height of 7 or 8 feet (fig. 9). The limbs should be cut flush with the trunk. The second pruning can be made 3 to 4 years after the first, and the third 3 to 4 years later. The removal of not more than one-third of the live crown is a safe general rule to follow in pruning. Several types of hand pruning saws, for use with ladders, and of pole saws are on the market.

THINNING FOREST TREES

Most pruned stands should be thinned so that maximum-quality growth may be obtained. The first thinning should be made when the trees begin to crowd the crop trees. This may be at the age of 15 or 20 years. Unless there is a demand for pine cordwood, it may not be possible to sell the material cut to meet the cost of the operation. By the time the stand is about 25 years old the value of the merchantable material removed in thinning should equal the cost. Later thinnings should be at about 10-year intervals until the trees are reaching maturity at about 55 to 60 years. In all thinnings, to reduce the amount of work, it is advisable to remove only those trees which actually interfere with the pruned or otherwise selected crop trees. Good results have been obtained by attempting to work toward a final crop of 100 to 125 crop trees per acre; these should be selected from the 150 to 300 pruned trees mentioned previously. Although there will be little demand for the small material removed in early thinnings, local mills will tend to use such material more and more from now on to encourage thinnings which will result in higher-quality logs in the future. Advice on pruning and thinning is available without charge from the extension or State forester in most of the States.

REMOVAL OF CANKERS

The ability of workmen to recognize different symptoms of the disease on pines and the care and thoroughness with which the cankers are removed determine the success of the work. In the Eastern States canker removal can be done any time during the year. Many of the cankers are located more easily during April and May, when the orange-yellow blisters make their appearance. The yellowish color that indicates the margin of the cankers is more or less obscured by dirt, and sometimes portions of it are indistinct and difficult to find. Rubbing the diseased bark with a wet cloth or brush, using laundry soap and water, followed by washing with clear water, will clean the bark and make the margin stand out more clearly. This is especially helpful in treating stem cankers, where accuracy in locating the edge of the canker is necessary for its successful removal.

There is a natural tendency to cut off branches too close to the cankers, especially when the latter are near the point where the infected branches join other branches or the trunks, and when the removal of larger branches farther back from the cankers might spoil the symmetry or lessen the beauty of the trees. Owners who employ others for this work should satisfy themselves that it is being done properly by learning the methods of treatment and the different stages of canker development. Haphazard cutting on infected trees should be avoided because it gives poor results and leaves unsightly stubs that spoil the appearance of the trees. Blister rust is not carried from tree to tree on tools used in treating infected pines, as are some fungus diseases, and so no precautions against reinfection from this source are necessary.

When large limbs are removed, care should be taken to prevent stripping off the bark below the cut. This is avoided by a double-cutting method. The limb is first sawed off about a foot beyond the point where the final cut will be made.[6] A preliminary cut is made a short distance into the limb on the under side, and then the limb is sawed through from above until the branch is severed. The remaining stub should then be removed in the same manner, but flush with the adjacent limb or trunk, and the edges of the wound smoothed with a sharp knife. This procedure is always advisable for limbs over 3 inches in diameter. Smaller ones can be removed in a single operation by first sawing part way through on the under side of the limb flush with the trunk and then completing the cut by sawing through from above. Limbs up to one-half inch in diameter can be cut off easily with pruning shears.

INFECTED BRANCHES

As the blister rust fungus infects pines through the needles, young cankers are more numerous on twigs and small branches than on the trunks. In removing branch cankers no time should be spent in searching for those that are undeveloped and difficult to find. Infected branches should be cut off at least 4 inches back of the yellowish edge of the canker to remove all the diseased bark, because the fungus extends a short distance beyond its edge (fig. 10). If any of it is left, the fungus continues to grow into the live bark. Infected branches are always cut off flush with the next healthy branch to eliminate the possibility of leaving stubs of branches and to reduce the liability of attack by other fungi and insects. When the canker edge is less than 4 inches from the next branch, both the infected and joining branches are cut off to assure complete elimination of the diseased area. Cankers on small twigs and branches near the ends of large limbs may be hard to find and reach. This makes their careful removal difficult. In such cases the cut usually can be made from 1 to 2 or more feet back of the canker. Whenever possible, this is a good practice to follow in removing infected branches. If the removal of cankers is combined with forest pruning, the infected branches should be cut off flush with the trunk along with the healthy ones for the height to which the trees are pruned.

[6] For details of general tree surgery work, see Farmers' Bulletin 1896, First Aid for Wounded Shade Trees, by Rush P. Marshall.

FIGURE 10.—Branch infection in a 12-year-old pine tree. *a* and *b* indicate the yellowish edge of the canker; *c*, the point where the branch should be cut off to prevent the disease reaching the trunk. (Photograph by the New York Conservation Commission.)

In cases where the edge of a canker is less than 4 inches from a trunk, the limb is cut off flush with the stem, and the bark is removed for a sufficient distance around the base of the limb to allow a full 4 inches between the edge of the canker and the edge of the wound

The amount of bark to be removed from the trunk will depend on the distance between the edge of the canker and the stem. If the canker has reached the stem, the treatment subsequently described for trunk cankers should be followed (fig. 11).

FIGURE 11.—Blister rust infection on white pine. Infected limb, *c*, on an 18-year-old tree, showing how the disease has worked back into the trunk from the original point of infection at *d*. The dotted line, *b*, indicates the margin of the canker on the trunk. The infected limb with all diseased and healthy bark inside the solid line *a* must be removed to save the tree. (Photograph by the New York Conservation Commission.)

Cankers on the main axis of large limbs sometimes can be treated successfully by cutting out all the diseased bark. The application of this method of treatment is governed by the location of the canker, its distance from the trunk, the extent to which it has girdled the limb, and the value of the limb to the tree. When it is apparent that a large limb has little chance of recovering if treated, it is better to cut it off flush with the next larger limb or with the trunk. In general, it is not

advisable to try to save large limbs by cutting out the cankered bark, except in instances where the limbs are essential to the life or beauty of highly valuable ornamental pines.

INFECTED TRUNKS

The trunk is the most important part of the tree to be considered and the most difficult to treat. When it is reached by the rust, the resulting canker gradually encircles the trunk and causes the death of the tree. The larger the trunk, the longer it takes for the completion of the girdling process.

Stem cankers have a more or less diamond- or spindle-shaped outline, being wide in the center and tapering toward both ends. They

FIGURE 12. Trunk canker in thick, rough bark, with a sunken area in the center. The edge of this canker cannot be determined from external symptoms.

extend vertically along the trunks in the early years of development, gradually becoming slightly spiral as the lengthwise growth of the canker increases. The infected bark can be removed without difficulty at any time but comes off most easily during the active growing season. Sometimes the margin of a canker is partly hidden by a hard layer of pitch. In such cases workmen usually can guess where it is located from the shape and size of the canker and the portion of the margin that is visible. This is not always practicable when the lower half of the canker is covered completely by pitch, when the discolored margin is so indistinct that its edge can not be outlined, or when the canker is located in the thick, rough bark of old trees (fig. 12). Under these conditions usually no attempt should be made to remove the canker.

Before beginning to cut out the diseased bark, clean the canker margin with soap and water. This removes the surface dirt and brings out more clearly the yellowish margin of the canker. After locating the edge of the canker, make allowance for a safety zone from 1½ to 2 inches wide laterally and from 3 to 4 inches longitudinally. Since there is usually some uncertainty about the exact margins of cankers and the distance the fungus extends beyond the yellowish edge, wider zones should be allowed when feasible. As the fungus grows faster longitudinally than laterally, it is good practice to increase the width of the safety zone an inch or two at both ends.

The area of bark to be removed is carefully outlined by furrowing the bark with a knife. With a sharp, hook-pointed knife, cut through the bark around the entire canker, carefully following the furrow. Then peel off the bark within the area outlined by the cut, taking care to clean the surface by carefully scraping the wound to remove all remnants of the inner bark. Trim the bark around the edge of the wound with a sharp knife and smooth all bruised or torn places. All wounds, whether on the main stem or on large limbs, should be made V-shaped at both ends (fig. 13). This assists the wound in healing and usually helps to prevent the bark from dying back at these points. Treated cankers should be kept under observation for several years to make sure that all the fungus was removed and that no further growth takes place in the bark.

The treatment of stem cankers is seldom advisable if the bark must be removed from more than one-half the circumference of the stem at any point. Trees may survive for several years when only one-third of the bark remains at the point of treatment, but they are greatly weakened, and, unless they are very valuable, it is better to replace them. If a canker is near the top of the stem, the affected portion of the crown may be cut off without entirely spoiling the appearance of the tree, as usually one or more of the branches in the whorl below the cut will soon grow upward and provide a new top.

Whether to treat or cut down ornamental trees with infected trunks will depend upon their size and value, the extent to which the stem has been girdled, and the distance of the canker from the ground. Even if treatment is impracticable, the trees will probably remain green and useful as ornamentals for several years. In such cases the owner may prefer to keep them until they become unsightly or die from the rust. Meanwhile other trees can be set out nearby to maintain esthetic values when the diseased trees are removed.

FIGURE 13.—Stages in the treatment of a pine stem with a blister rust canker. *A*, *a*, Place where the infected limb was cut off close to the stem; *b*, growing edge of the canker; *c*, outline of the area within which bark must be removed; *d*, white pitch streaks; *e*, part of the bark peeled off, showing wood. *B*, The wound made by removing all the diseased bark. (Photographs by National Park Service.)

TOOLS

The tools needed for the removal of blister rust cankers are few and inexpensive. Infected branches on small trees can be easily and quickly removed with pruning shears. On large trees most of the infections which are near the ends of branches can be removed with the help of ladders, climbing ropes, pole shears, and long-handled pruning saws. A wide-toothed pruning saw is the best tool for removing large branches and limbs. If only a little work is necessary, other common types of cross-cut saws will serve nearly as well. A hawkbill (hook-pointed) knife gives good results in cutting and peeling off diseased bark. Always wear soft-soled shoes when climbing through the trees, to avoid bruising and injuring the bark.

CARE OF WOUNDS

It is not necessary to treat small wounds caused by cutting off infected branches, but it is important to protect large ones resulting from the removal of limbs and stem cankers to help prevent attacks from other fungi and from insects.

FIGURE 14.—Blister rust cankers successfully treated by removing the diseased bark. *A*, Early stage in healing; callus has formed around the edges of the wound. *B*, Scar nearly closed by healing edges of bark; large scars usually are not completely covered by callus.

Many authorities recommend treating wounds more than 2 inches wide. A dressing of bordeaux paint, made by mixing equal parts by weight of commercial dry bordeaux mixture and linseed oil, can be

used. Many tree paints prepared especially for use in protecting wounds are readily obtainable.

The removal of stem cankers results in a copious exudation of pitch that seals the exposed wood and bark cells. Sometimes there is such an abundant flow that it runs down the branch or stem. It then dries and hardens, leaving white, chalklike streaks of unsightly appearance. This can be lessened by scraping the surface of the wound and sealing it with shellac as soon as the bark is removed. After the shellac is dry, apply a coat of thick, bark-colored paint. This treatment will make the cut surfaces much less noticeable and help to prevent infection by wood-rotting fungi. It is good practice to repaint wounds when the first coat begins to lose its protective value.

Wounds resulting from the removal of cankered bark heal around the edge and form a callus. If the wound left by the treatment is small and occurs on a young, fast-growing tree, the callus gradually closes over and may completely cover the injured area. The larger the wounds, however, the less the possibility of their being completely covered by callus. In such cases callus forms around the edges of the wound, leaving some of the wood exposed, and may never close it completely (fig. 14). This is usually the case with slowly growing older trees that are not rapidly increasing in diameter.

REINSPECTION

Reinspection accomplishes the double purpose of detecting cankers that were undeveloped or missed in previous work and of checking the thoroughness of canker removal already done. It is often impossible to find all the infections at one inspection, particularly on large trees. Some of the young cankers will be overlooked, and others will not be developed sufficiently to be found because of the time required for cankers to become visible after pine infection takes place. The few which are missed will continue to grow, and most or all of them can be found 3 years later. Overlooking one infection on or near the main stem is much more dangerous to the life of the tree than missing the more distant cankers located near the ends of branches.

Valuable trees should be reinspected the first and fourth years after treatment, and every third year thereafter until no further infections can be found. This will result in the detection and elimination of any cankers that were overlooked or that have matured since the last treatment. The scars of cankers previously treated should be examined at the same time and, if necessary, repainted. If the original treatment was unsuccessful or if insects have bored into the edges of the callus, the affected bark should be removed and the wound painted. Insect attacks can be recognized by small holes in the bark and by lumps of brownish pitch exudations along the edges of the scar. The more valuable the tree, the more important is reinspection.

PREVENTION OF NEW PINE INFECTIONS

The white pines are widely distributed in this country, and in many States they have been planted extensively as ornamental and forest trees. Cooperative programs for the control of blister rust in the different forest regions are largely confined to areas selected for the

production of white pines as a forest crop and to public parks and recreational areas where these trees have high esthetic values. Outside such control areas a great many native white pines occur extensively as ornamental groups, windbreaks, landscape plantings, recreational groves, and marginal forest stands, which the owner may consider worth protecting from blister rust infections by *Ribes* eradication in their vicinity and, if the trees are already diseased, by canker removal.

Before any work is undertaken to save infected trees by cutting off branch cankers or removing diseased portions of the trunk, the pines should be protected from further infection by the eradication of *Ribes*. The proper removal of these plants will eliminate the source of new infections. Otherwise the treatment of infected pines only delays the death of the trees because new infections will continue to occur from year to year. Under such conditions annual inspection for early discovery and removal of new cankers is necessary to prevent them from ultimately killing the trees. The yearly repetition of this operation is not only expensive, but the pines become unsightly and may ultimately die. The eradication of *Ribes* to prevent infection of white pines, therefore, should be completed before removal of cankers from the diseased trees is begun.

Occasional infections may take place from European black currants (*Ribes nigrum*) and from large groups of other *Ribes* located at distances up to about 1 mile from pines. Also, wild *Ribes* and escaped cultivated bushes in the vicinity of the trees are apt to cause some infection. A careful inspection for such bushes in the vicinity of the pines every few years will aid in preventing occasional pine infections. Owners should consult the official in charge of blister rust control in their locality or the State forester concerning the application of control measures in the vicinity of their white pines.

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